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Characterizing Complexity in a Semiconductor with Optical Feedback from two Mirrors

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Characterizing Complexity in a Semiconductor laser with Optical Feedback from two Mirrors

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Introduction

Lasers are stable devices with many different applications. They can easily be perturbed to create complex dynamics. One interesting regime in semiconductor lasers is that where the output intensity of the laser emits a sequence of non-regular optical spikes. This behavior mimics that of neurons. This can then be used to potentially study some of the most complex systems, like neuronal spikes [1].

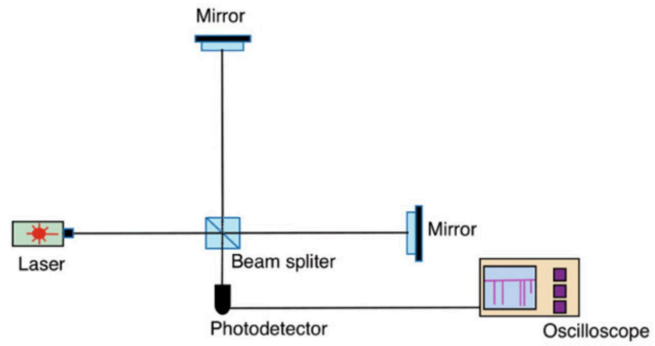
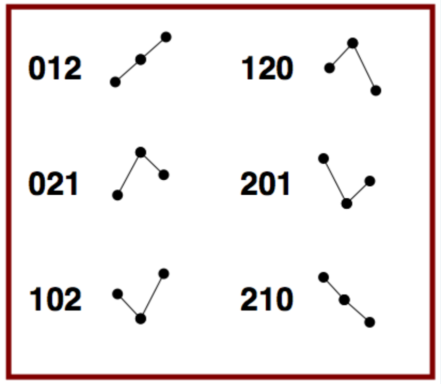


Fig.1. Setup used in this experiment. Light from the laser is sent to two mirrors to get feedback and induce complex dynamics.

In this experiment one semiconductor laser is set up with two mirrors. A beam splitter is used to get the laser to both of the mirrors. Feedback from the mirrors induces complex dynamics in the output intensity of the laser.
The data is collected using a fast oscilloscope (1 GHz). The output intensity presents drop-outs or jump-ups, both of which we characterize using an ordinal pattern analysis method.

Analysis method

- The method of experimentation involves sequencing data into a series of ordinal patterns, also known as words. These words are computed following the Bandt-Pompe method [2]. They capture temporal correlation between consecutive events. This technique is powerful and robust to unveil hidden structure in apparently random dynamics.



Results

Behavior with one mirror

- With just one mirror giving feedback we see the dropouts that show the complex behavior.
- These dropouts are characterized using words, from which the probabilities of them occurring are calculated.

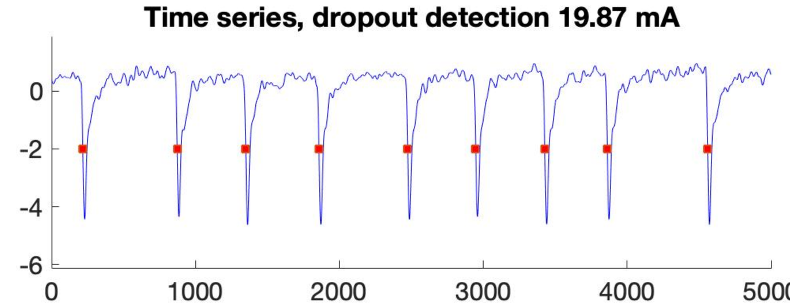


Fig.2. Time series of the output intensity of a semiconductor laser with optical feedback from one mirror. The dots indicate drop-out detection.

Behavior with two mirrors

- The behavior changes when both mirrors are in the system.
- With feedback from both mirrors the behavior changes from drop-outs to jump-ups depending on the current.

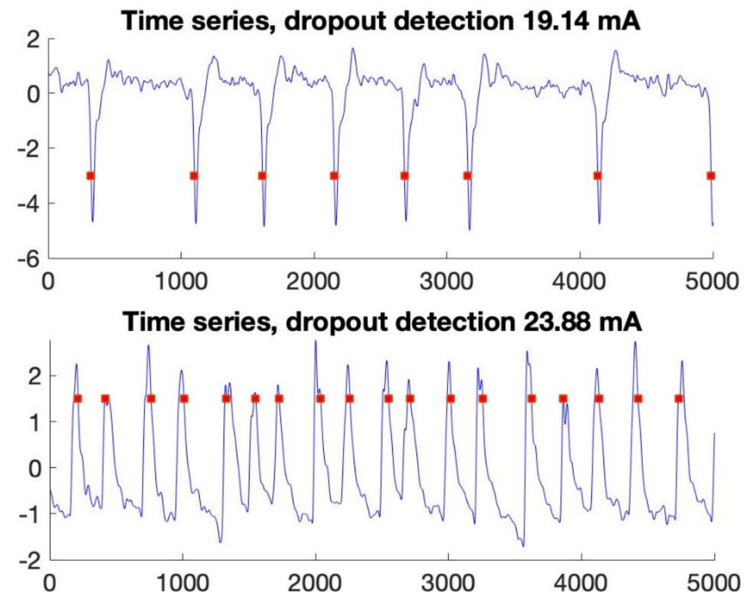


Fig.3. Time series of the laser with feedback from both mirrors.

Words probabilities versus pump current

- Words probabilities versus pump current show the change in temporal correlations. For feedback from a single mirror there is an region where the dynamics is clearly deterministic, while the rest is compatible with a stochastic process.
- With feedback from both mirrors, the most structured behavior disappears and it becomes compatible with a stochastic nature. The competence between both mirrors kills the deterministic dynamics.

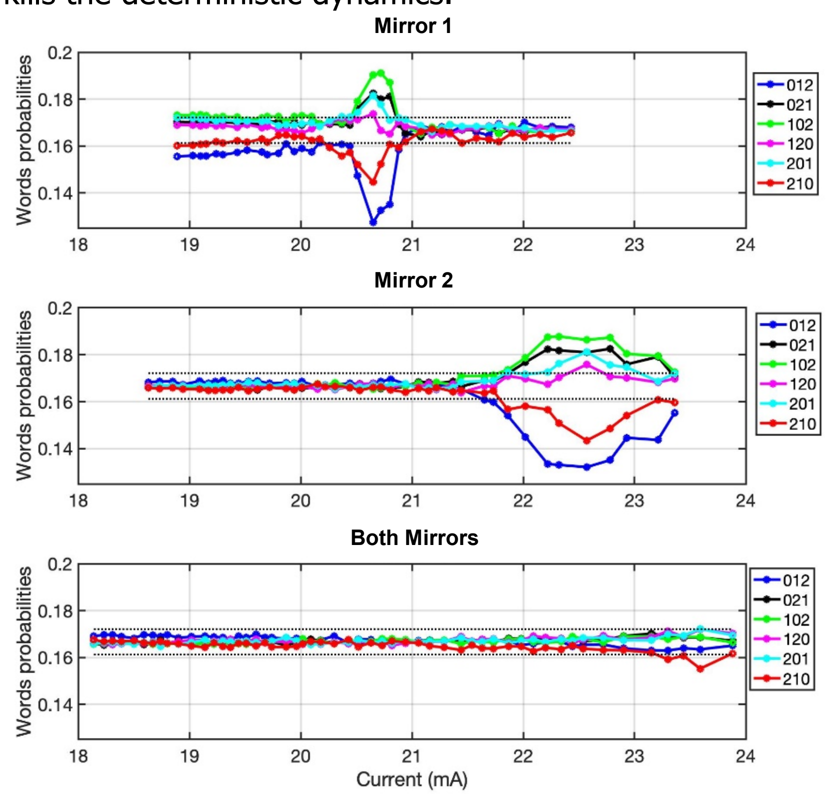


Fig.4. Words probabilities of dimension 3 versus pump currents.

Conclusions

- Feedback on a semiconductor laser induces complex dynamics on the laser
- The effect of having two feedbacks changes the type of events from drop-outs to jump-outs.
- Two feedbacks modify the dynamics of the system, and induce a behavior compatible with stochasticity.
- With feedback from two mirrors, the dynamics observed is not distinguishable between the drop-outs and the jump-ups regime.

References

[1] A. Aragoneses et al., "Unveiling the complex organization of recurrent patterns in spiking dynamical systems". Sci. Rep. **4**, 4696 (2014).
[2] C. Bandt & B. Pompe, "Permutation entropy: a natural complexity measure for time series". Phys. Rev. Lett. **88**, 174102 (2002).